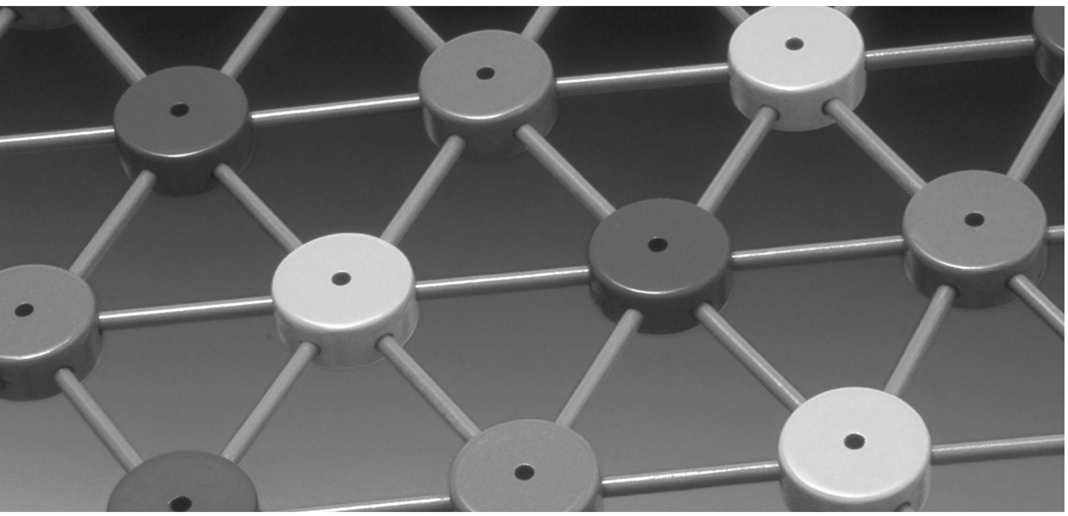
Chapter Nine

Resource Integration / Alternative Strategy Comparisons



Chapter 9: Resource Integration/ Alternative Strategy Comparisons

The resource integration phase of Energy Vision 2020 identified over 2,000 strategies using various mixes of supply-side and customer service options. From an extensive series of evaluations, several strategies emerged that offer competitive electricity for TVA's customers.

Seven strategies produce low cost, low electric rates, low debt, and low environmental impacts. At the same time, these strategies increase customer value and opportunities for economic development.

Options and strategies were also evaluated for several key uncertain events in the future (e.g., load growth, natural gas prices). These evaluations have identified several strategies, which provide flexibility to adapt to uncertain events.

The overall results of the resource integration are summarized in the long-term plan at the end of this chapter.

Much of the material in this chapter describes the results of computer analyses of many variables related to planning the power system. As such, some of the material is quite complex. For this reason, graphical charts have been included to show many of the key results that have been considered for future resource decisions.

Readers interested in a more qualitative summary of the results can review this Chapter's Final Evaluation section and the last section, which deals with the long-term plan.

This Chapter Includes:

- What Does Integration Mean?
- Review of Criteria and Options
- Uncertainties and Futures Development
- Strategy Development
- Decision on Nuclear Power
- Final Strategy Evaluation
- Environmental Consequences
- Managing Risk – Hedging Uncertainties
- Final Evaluation
- The Long-Term Plan – Preferred Alternative

Resource Integration/ Alternative Strategy Comparisons

What Does Integration Mean?

Energy Vision 2020 has its own language. Integration means combining options to create strategies and combining uncertainties to create futures. Strategies and futures are then combined to create scenarios. These scenarios are then evaluated against the plan's criteria.

As discussed in Chapter 2, Energy Vision 2020 uses multi-attribute tradeoff analysis to integrate strategies, futures, and evaluation criteria. This integration process is summarized in *Figure 9-1*. Input from the public and TVA employees was a starting point for Energy Vision 2020. TVA received more than 1,300 comments, which were translated into evaluation criteria, resource options, and uncertainties.

One of the primary goals of Energy Vision 2020 is to develop a long-term plan that provides flexibility.

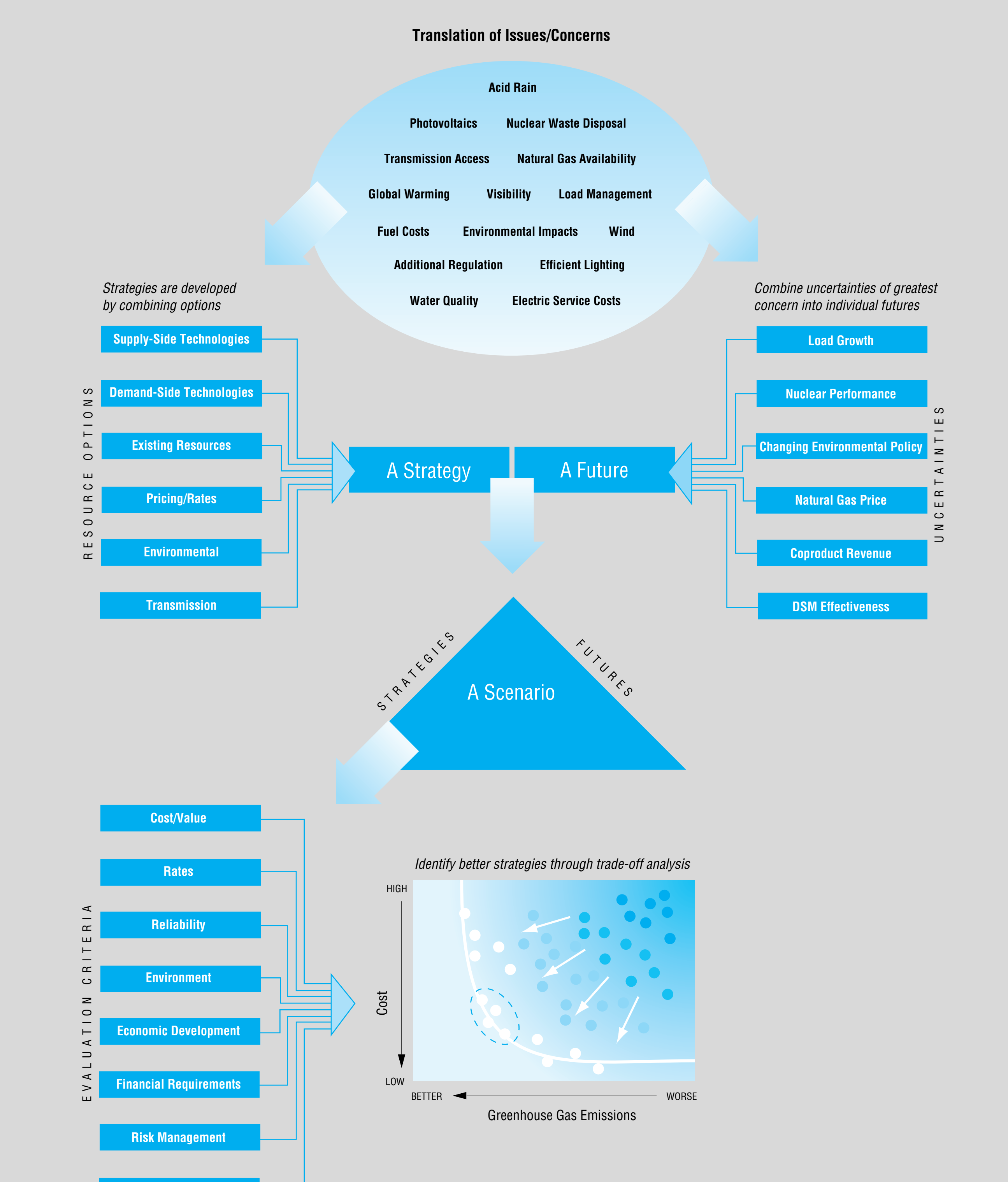
Evaluation criteria are based on values people hold; they are used to define and judge different resource plans or strategies. As indicated in *Figure 9-1*, criteria were identified in eight areas: cost and value, electric rates, reliability, environment, economic development, financial requirements, risk management, and equity among rate classes.

Strategies are based on actions TVA can control and are largely based on supply-side options, demand-side technologies, existing resources, and environmental control options. Several pricing or electric rate options and transmission options were considered, but not to the extent of the other resource options.

Each strategy was designed to meet the capacity requirements for either the low, medium, or high load forecast. Beginning with the existing coal, nuclear, and other power resources, new resource options were added to meet the capacity requirements. These options included peaking and base-load supply-side and demand-side resources as well as environmental control technologies to reduce pollutants such as sulfur dioxide, nitrogen oxides, and carbon dioxide.

From the public input, uncertainties were identified and combined into futures. Futures are largely outside of TVA's control. The key uncertainties are load growth, nuclear performance, changing environmental policy, natural gas prices, the price or revenue from chemical coproducts and the effectiveness of demand-side management programs. The futures create a highly uncertain environment that creates cost, electric rate, and other risks to TVA's customers. These risks must be managed in order to create a desirable strategy.

FIGURE 9-1. **Energy Vision 2020 Process**



The Energy Vision 2020 process translates concerns into evaluation criteria, options, and uncertainties. Options are combined into strategies and uncertainties into futures. Strategies and futures are combined into scenarios. Each scenario is evaluated against the criteria and analyzed using trade-off analysis.

Strategies and futures are combined into a scenario—thus, one strategy and one future produces one scenario. Since each scenario is evaluated using the same criteria, all strategies and resource options—supply or demand—are evaluated on a level playing field.

Since each scenario contains a strategy for a given future, the strategies can be judged or evaluated on all the criteria.

To evaluate these strategies, TVA uses a number of custom and off-the-shelf computer applications. One of these applications, MIDAS, is a program tailored for TVA by the Electric Power Research Institute. The MIDAS computer application can take 30 years of power demand forecasts and simulate how the TVA power system would be run. At the same time, MIDAS also estimates financial results under various assumptions. These assumptions deal with such variables as load growth, the price of fuel, or a change in rates. As assumptions change—for example, load growth increasing from 2 percent a year to 3 percent—a new simulation is run. Each simulation provides forecasts of future capacity, type of capacity, generation, and financial forecasts of cost, debt, and electric rate measures.

The results of the evaluations produce estimates for each of the 42 criteria. The estimates of the criteria are provided for each possible combination of strategies and futures. The process produces thousands of data elements that must be analyzed.

The large volume of results is analyzed systematically using the trade-off analysis. This trade-off analysis is necessary because more than one evaluation criterion or measurement is relevant to evaluating the strategies.

The purpose and nature of trade-off analysis are shown graphically in *Figure 9-1*. The axes of the graph identify two evaluation criteria or attributes. In this example, the cost of electricity ($/kilowatt-hour) is on the vertical axis and greenhouse gas emissions (tons) are on the horizontal axis. The results for each strategy are plotted on the graph for various futures.

If there were only two criteria that TVA had to consider, the ideal strategy would be located closest to where the two axes meet (in the lower left hand corner). In this example, strategies within the dotted line would be those with the lowest electricity costs and the lowest greenhouse gas emissions.

Once trade-offs are analyzed, strategies are modified and improved where possible to move them closer to the corner. In cases where an unavoidable trade-off exists, the decision-maker must choose between strategies. As an example, if there is no strategy with both the lowest costs and the lowest greenhouse gas emissions, the decision-maker may have to choose one over the other. After extensive reviews of different trade-offs, those strategies that, in the opinion of the decision-maker, best meet the criteria and provide flexible choices are developed into the long-term resource plan.

The result of this integration is a plan that can be interpreted objectively. It sounds complicated, but it is not so difficult when broken down step by step. It is TVA's intention to ensure every possibility is reviewed to provide a better tomorrow for the Tennessee Valley. This process creates a valuable management tool for TVA's decision-making during the next 25 years.

Review of Criteria and Options

As explained in Chapter 5, TVA established 42 criteria in the early stages of the Energy Vision 2020 process. Of these, 8 are related to cost and rates, 2 are related to debt, 2 are related to economic development in the Valley, and the remaining 30 are related to the environment. These criteria represent stakeholder values and are used to evaluate strategies.

Of the 188 resource options considered, 120 are supply-side options, 60 are customer service options, 2 are rate options, 4 are environmental control options, and 2 are transmission options. Chapter 7 explains how supply-side options were developed, and Chapter 8 covers customer service options. Discussions about environmental control options are also found in Chapter 7.

TVA sorted and ranked all 188 options according to selected criteria. The rankings were used as an aid in developing strategies. Ranking results are found in Volume 2, Technical Document 8, Resource Integration.

Uncertainties and Futures Development

Uncertainties also were evaluated. As explained in Chapter 2, uncertainties are those concerns that impact the Valley's energy future and are beyond TVA's control. For example, the future level of natural gas prices is an uncertainty and is significant because natural gas is a source of fuel for several supply-side options.

TVA identified 40 uncertainties, which were reduced to the 7 most important: load growth, nuclear cost and performance, greenhouse gas (carbon dioxide) regulations, air and water quality regulations, price of natural gas, revenue from chemical coproducts, and effectiveness of demand-side management. A description of how TVA accounted for uncertainty is found in Volume 2, Technical Document 8, Resource Integration. The uncertainties identified in the plan are shown in *Figure 9-2.*

TVA combined the seven uncertainties in every imaginable combination to produce possible futures. For example, one future included high electricity sales growth, high cost of natural gas as a fuel, and increased regulation of greenhouse gases. This exhaustive process produced 972 futures.

FIGURE 9-2. **Range of Values of Key Uncertainties**

	Low	Medium	High
1. LOAD GROWTH (Peak)			
• 1994-2000	0.0%	2.2%	3.4%
• 2000-2020	0.0%	1.9%	3.2%
2. NUCLEAR ISSUES			
• Capacity Factor	55%	67%	86%
• O&M (94$) all escalate at 4.5%	55 $/kW	69 $/kW	83 $/kW
• Capital Cost ($m)			
– Bellefonte Unit 1	1311	2622	3470
– Bellefonte Unit 2	912	1824	2420
– Browns Ferry Unit 1	1187	2374	3150
– Watts Bar Unit 2	1097	2194	2910
3. CARBON DIOXIDE COMPLIANCE (94 $) (Control cost over 1990 level)	0 $/Ton	5 $/Ton	10 $/Ton
4. AIR & WATER CONTROLS (94 $) (Add to existing coal units 2004)	0 $/kW	150 $/kW	250/425 $/kW
5. PRICE OF NATURAL GAS			
• Price (2000 $)	256 ¢/MBtu	342 ¢/MBtu	418 ¢/MBtu
• Escalation	2.4%	5.3%	7.9%
6. COPRODUCT REVENUE (2000 $)	91 $/Ton	262 $/Ton	320 $/Ton
7. DSM EFFECTIVENESS (MW peak reduction in 2010)	3124	5494	8219

Over 40 uncertainties were evaluated, and the 7 uncertainties with the greatest impact on the criteria are shown in this figure. For each uncertainty, low, medium, and high values are shown.

Strategy Development

In developing strategies, TVA attempted to identify ones that best addressed the evaluation criteria and uncertainties. Using the ranking process, TVA combined the customer service options into four demand-side management blocks and two beneficial electrification blocks, as explained in Chapter 8. The supply-side options were combined into 31 categories, including coal, gas, nuclear, renewables, and independent power production. These 31 categories were used to create diverse strategies to address the established criteria and uncertainties. There were three environmental control options, two electric rate options, and two transmission option. Each strategy contained short- and long-term supply-side options, customer service options (demand-side management or beneficial electrification), environmental control options, electric rate options, or transmission options.

From the 6 customer service blocks, 31 categories of supply-side options, 3 environmental control options, 2 electric rate options, and 2 transmission options, over 2,000 strategies were produced. Each strategy was further subdivided into a short-term period, 1996-2005, and a long-term period, 2006-2020.

TVA examined all of these strategies using the multi-attribute trade-off analysis described earlier in this chapter and in Chapter 2. In these early evaluations each strategy was evaluated for each criterion. This process created over 40,000 estimates of the evaluation criteria.

From these early evaluations many strategies were eliminated and new strategies were created. Strategies were eliminated based on the evaluation criteria. Strategies were generally eliminated only if there were clearly superior strategies. These evaluations resulted in 7 strategies emphasizing the evaluation of customer service options, 14 strategies relating to supply-side options including nuclear options, and 16 strategies that were mixed strategies or combinations of supply, customer service, environmental control, pricing, and transmission options. These 37 strategies best addressed the evaluation criteria and uncertainties.

These strategies were combined with futures, then scenarios were evaluated using the multi-attribute trade-off analysis. This process produced another set of thousands of estimates of evaluation criteria for the different futures.

The evaluation of 37 strategies was reviewed with the stakeholder Review Group at its January meeting. As the analysis continued, some strategies were eliminated, while others were refined to make new strategies. These new strategies were reviewed at the February and March meetings of the stakeholder Review Group.

During these three rounds of reviews, additional analysis concentrated on two areas. First, during the January review, there were no strategies with both low rates and low environmental emissions, particularly carbon dioxide (CO_2) emissions, in the 37 strategies evaluated. (Carbon dioxide is generally a good indicator of the air quality performance of all strategies.) In subsequent rounds, low cost renewables—which have few emissions—were given a more prominent position, and the rates/environment trade-off improved. The stakeholder Review Group recommended several strategies to improve on this trade-off.

Second, changes in the electric utility industry are creating additional uncertainty. Increasing competition increases the uncertainty in load growth and the future price of electricity. Since both load growth and price uncertainty create cost and electric rate risks to customers, TVA developed a set of resource options that provide the flexibility to adapt to these uncertainties. These resource options permit TVA to manage the risk associated with uncertain load growth and electric prices.

As described in Chapter 7, these flexible resource options are similar to call options found in financial markets. Based on a request for proposals, hundreds of call options for purchasing power were identified. In addition, TVA identified flexible internal options. These options are largely based on traditional supply- and demand-side options, but with the flexibility to stop or start construction on a project or program.

These flexible resource options, along with the traditional resource options, were evaluated using new techniques. These techniques are based on financial options valuation models and extensions of decision analysis models.

Approximately 400 flexible resource options were evaluated. From these evaluations, the best flexible resource options were identified and strategies containing these options were developed.

The three rounds of evaluations and the additional analysis performed during the period resulted in 21 strategies. These 21 strategies were reviewed by the stakeholder Review Group in March. These strategies are identified in *Figure 9-3*.

For purposes of comparison, TVA also retained Strategy D. Strategy D is the reference or "No Action" strategy for Energy Vision 2020. The "No-Action" strategy was to identify those resource options that TVA would most likely have employed to meet demand in the absence of the information and analysis produced as a result of the Energy Vision 2020 process. Taking into account the difficulties TVA has encountered in completing the nuclear units that it has had under construction, it was determined that TVA would likely have looked to some mix of combined cycle combustion turbines, new coal-fired units, and limited amounts of purchased power. These became the core elements of the Energy Vision 2020 "No Action" strategy and formed the reference strategy for purposes of analysis and benchmarking integration results across alternative strategies.

Decision on Nuclear Power

During the course of Energy Vision 2020, TVA's staff performed a review of issues involving unfinished or inoperative nuclear units and their impacts on rates, debt, long-term costs, and flexibility for meeting future power needs. This review was based on the more than 2,000 strategies evaluated using the multi-attribute trade-off analysis.

The three major concerns identified by TVA stakeholders—debt, competitiveness, and nuclear power—are interrelated. In the opinion of many stake-

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies**

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
STRATEGY A Minimum CO_2 - Natural Gas Repowering of Existing Coal	Supply-side expansion relies on low emission options • Natural gas combined cycle repowering of several existing coal units • Combustion turbines • Combined cycle • Fuel cells • Hydro modernization	Maximum use of DSM (three blocks) reduces need for generation	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals CO_2 and other fossil emissions • CO_2 penalty added to assumed cost of generation options to shift generation to lower emission sources • Moderate level of biomass (waste wood) cofiring (1.3%) at existing fossil units	No special pricing policy is used
STRATEGY B Minimum CO_2 - Natural Gas Repowering of Existing Coal and Renewables	Supply-side expansion relies on low emission options and renewables • Natural gas combined cycle repowering of several existing coal units • Combustion turbines • Landfill and coalbed methane • Wind • Refuse-derived fuel repowering of an idled coal plant • Biomass-fueled plants • Fuel cells • Hydro modernization	Maximum use of DSM (three blocks) reduces need for generation	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • CO_2 penalty added to assumed cost-of-generation options to shift generation to lower emission sources • Moderate level of biomass (waste wood) cofiring (1.3%) at existing fossil units	No special pricing policy is used
STRATEGY C Low-Cost Producer (Coal-Based)	Supply-side options emphasize coal for all base-load options • Combustion turbines • Small pulverized coal plant at existing site (Shawnee 11) • Pulverized coal with scrubbers • Clean coal technologies • Hydro modernization	Maximum use of DSM (one block) reduces need for generation	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing fossil units	Time-of-day rates reduce peak demand growth
STRATEGY D Combined Cycle, Purchased Power, Coal (Reference)	Supply-side options emphasize a blend of TVA-built, IPPs, and cogenerators to reduce production cost and debt • Combustion turbines • Combined cycle • IPP and cogeneration natural gas combined cycle • IPP coal • Clean coal technologies	Low-price block of DSM (block one) reduces demand with minimum rate increase	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing fossil units	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** *CONTINUED*

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy E Maximum Customer Value Index - Off-System Sales, High Beneficial Electrification, Declining Block Pricing	Supply-side options mix emphasizes coal expansion for low production cost • Combustion turbines • Small pulverized coal plant at existing site (Shawnee 11) • Clean coal technologies • Pulverized coal with scrubbers • Hydro modernization	Attempt to increase customer value (low rates and low-cost services) by a combination of: • Low-price block of DSM (block one) reduces demand with minimum rate increase • High level beneficial electrification provides services and increases power sales • Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	Declining block pricing promotes electricity use
Strategy F Low Total Resource Cost/High DSM	Supply-side options mix emphasizes coal expansion and low-cost renewables for low production cost • Combustion turbines • Clean coal technologies • Landfill and coalbed methane • Pulverized coal with scrubbers • Hydro modernization	Maximum use of DSM (three blocks) reduces need for generation	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy G Maximum Sales	Supply-side options mix emphasizes coal expansion and low-cost renewables for low production cost • Combustion turbines • Clean coal technologies • IPP coal plant • Pulverized coal with scrubbers • Hydro modernization • Compressed air energy storage • Combined cycle • Small pulverized coal plant at existing site (Shawnee II)	No DSM High-level beneficial electrification Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing fossil units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** CONTINUED

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy H Maximum Capacity Diversity	Supply-side options mix emphasizes many diverse smaller options • Combustion turbines • Combined cycle • IPP and cogeneration combined cycle • IPP coal plant • Clean coal technologies • Compressed air energy storage • Landfill and coalbed methane • Wind • Fuel cells • Biomass (short rotation woody crop) plant • Refuse-derived fuel stoker plant • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • Moderate level of biomass (waste wood) cofiring (1.3%) at existing fossil units	No special pricing policy is used
Strategy I Bellefonte Nuclear Partnership	Supply-side options include traditional expansion options with a Bellefonte Nuclear Partnership • Combustion turbines • Combined cycle • IPP and cogeneration combined cycle • IPP coal plant • Clean coal technologies • Bellefonte nuclear partnership	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • Moderate level of biomass (waste wood) cofiring (1.3%) at existing fossil units	No special pricing policy is used
Strategy J Bellefonte Coproduct, Renewables, IPPs	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • IPP combined cycle • Landfill and coalbed methane • Clean coal technologies • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** *CONTINUED*

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy K Defer and Build BFN 1 and WBN 2 with Reference Expansion	Supply-side expansion features completion of two nuclear units and traditional expansion options • Combustion turbines • BFN 1 and WBN 2 • IPP and cogeneration combined cycle • Combined cycle • Clean coal technologies • IPP coal plant	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units	No special pricing policy is used
Strategy L Minimum CO_2 with Less DSM (a variation of Strategy B)	Supply-side expansion relies on low emission options and renewables • Natural gas combined cycle repowering of several existing coal units • Combustion turbines • Combined cycle • Landfill and coalbed methane • Wind • Refuse-derived fuel repowering on an idled coal plant • Biomass fueled plant • Fuel cells • Hydro modernization	Low-price and low-cost DSM (two blocks) reduces need for generation	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • CO_2 penalty added to assumed cost of generation options to shift generation to lower emission sources • Moderate level of biomass (waste wood) cofiring (1.3%) at existing fossil units	No special pricing policy is used
Strategy M Combined DSM and Off-System Sales (a variation of Strategy F)	Supply-side options mix emphasizes coal expansion and low-cost renewables for low production cost • Combustion turbines • Pulverized coal at an existing plant • Clean coal technologies • Landfill and coalbed methane • Pulverized coal with scrubbers • Hydro modernization	Low-price and low-cost DSM (two blocks) reduces need for generation Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy N Decentralized Generation with More Renewables	Supply-side options mix emphasizes many diverse options • Combustion turbines • Combined cycle • IPP and cogeneration combined cycle • IPP hydro plant • Landfill and coalbed methane • Wind • Fuel cells • Refuse-derived fuel stoker plant • IPP coal plant	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** *CONTINUED*

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy O Bellefonte Coproduct, More DSM, More Off-System Sales (a variation of Strategy J)	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • IPP combined cycle • Landfill and coalbed methane • Clean coal technologies • Hydro modernization	Low-price and low-cost block of DSM (two blocks) reduces need for generation Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy P Low-Cost Renewables, Low-Price DSM, Repowering	Supply-side expansion relies on low emission options and renewables • Natural gas combined cycle repowering of several existing coal units • Combustion turbines • IPP combined cycle • Clean coal technologies • Compressed air energy storage • Landfill and coalbed methane • Wind • Pulverized coal • Refuse-derived fuel repowering of an idled coal plant • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • CO_2 penalty added to assumed cost of generation options to shift generation to lower emission sources • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy Q Flexible Strategy with External Options	Supply-side expansion features purchase options with rights, but not obligations, to purchase power • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • IPP combined cycle • Purchase of peaking capacity • Flexible base capacity purchase • Flexible peaking capacity purchase • Landfill and coalbed methane • Clean coal technologies • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** *CONTINUED*

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy R Flexible Strategy with Internal Options	Supply-side expansion features preplanning, design, and siting work to support flexible start dates of TVA-built options • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • IPP combined cycle • Combined cycle • Purchase of peaking capacity • Flexible base capacity purchase • Landfill and coalbed methane • Clean coal technologies • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales	SO_2 • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy S Low Cost, Low Rates, Improved Environment (a variation of Strategy O)	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • IPP combined cycle • Landfill and coalbed methane • Clean coal technologies • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales spread fixed cost over more sales	SO_2 • Scrubbers are added at several existing units • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used
Strategy T Low-Cost Renewables, Low-Price DSM, Repowering, Bellefonte Coproduct Partnership (a variation of Strategy P)	Supply-side expansion relies on low emission options, renewables, and an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Natural gas combined cycle repowering of several existing coal units • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Combustion turbines • IPP combined cycle • Clean coal technologies • Compressed air energy storage • Landfill and coalbed methane • Wind • Pulverized coal • Hydro modernization	Low-price block of DSM (block 1) reduces demand with minimum rate increase	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • CO_2 penalty added to assumed cost of generation options to shift generation to lower emission sources • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used

FIGURE 9-3. **Characteristics of Energy Vision 2020 Strategies** *CONTINUED*

No./Name	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls	Pricing
Strategy U Low-Cost Renewables, More DSM, Repowering, Bellefonte Coproduct Partnership (a variation of Strategy P)	Supply-side expansion relies on low emission options, renewables, and an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Natural gas combined cycle repowering of several existing coal units • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Combustion turbines • IPP combined cycle • Clean coal technologies • Compressed air energy storage • Landfill and coalbed methane • Wind • Pulverized coal • Fuel cells • Hydro modernization	Low-price and low-cost DSM (two blocks) reduces need for generation	SO_2 • Gas repowering of some existing coal • Switching to lower sulfur coals at several existing units CO_2 and other fossil emissions • CO_2 penalty added to assumed cost of generation options to shift generation to lower emission sources • A level of biomass (waste wood) cofiring of 0.3%	No special pricing policy is used

holders, high debt is generally associated with a poor competitive position. Since the large capital expenditures necessary to complete TVA's nuclear units would increase TVA's debt, the possibility of completing these units contributes to a perception that TVA's competitiveness will suffer.

The question of how to proceed with four nuclear units—Bellefonte Nuclear Plant Units 1 and 2, Watts Bar Nuclear Plant Unit 2 and Browns Ferry Nuclear Plant Unit 1—is critically important to TVA and the region it serves. The total cost to complete or restore them to service as nuclear units is estimated to be about $9 billion—unquestionably a major investment by TVA's customers. But in addition to these costs, TVA considered these factors:

- Need for power in the future
- Cost and operating performance of other options that could replace the nuclear units
- TVA's long-term costs
- TVA's rising debt
- Impact of any decision on short- and long-term rates
- Environmental effects of various resource options

After receiving the staff's review, TVA's Board of Directors announced that TVA will not fund the completion of Bellefonte Units 1 and 2 and Watts Bar Unit 2 as nuclear units. In addition, Browns Ferry Unit 1 will continue in its current inoperative status. TVA will keep open alternatives for these units that would minimize short-term rates, increase long-term flexibility, minimize long-term costs, and limit debt.

Alternatives to completing these units as nuclear units include:

- Converting the units to another technology such as natural gas or coal gasification with a chemical coproduct
- Replacing these units with different types of supply- and demand-side resource options

The nuclear power report is found in Volume 2, Technical Document 8, Resource Integration.

Final Strategy Evaluation

The 21 strategies that remained following the third round of evaluation were compared using the evaluation criteria.

TVA used the 42 criteria to quantitatively compare the strategies. Several were selected as representative of the 42 criteria. These include a customer value test; total resource cost; impact on short-term rates; impact on total debt; emissions of carbon dioxide, sulfur dioxide, and solid waste; and annual average income in the TVA region.

Strategies were combined with futures to develop 20,000 scenarios. The scenarios were then evaluated against all 42 of the criteria, creating more than 850,000 data points. Each of these data points represents the numerical value for one criteria and one scenario.

In Energy Vision 2020, TVA used multi-attribute trade-off analysis extensively as an evaluation tool. Five trade-off graphs appear as illustrations in this section. These trade-off graphs provide a comparison of the 21 strategies for representative criteria for a mid-range future. This mid-range future consists of:

- Medium load growth
- Medium natural gas price
- Medium chemical coproduct price
- Medium nuclear performance
- Medium demand-side management effectiveness
- No additional environmental regulations
- No additional carbon dioxide regulations

(Medium values are identified with the list of uncertainties in *Figure 9-2.*) This mid-range future is judged to be one of the more probable futures and is used in the initial evaluations.

Figures which follow show trade-off graphs in which the 21 strategies are evaluated against debt, long-term costs, short-term rates, carbon dioxide emissions, economic development, and customer value. Trade-off graphs are plotted such that the best performing strategies (relative to the other strategies) appear in the lower left corner of the graphs. Best performing strategies have the lowest (or highest) value for the two criteria plotted on the chart. Strategies in this area are enclosed within a box. A discussion of the strategies within the box that will be carried forward for further analysis follows:

Debt in Year 2001 Versus Total Resource Costs

Nine strategies result in low debt and low long-term costs (long-term costs to customers over the 25-year period are identified as total resource costs [TRC]). These 9 are Strategies F, J, M, O, Q, R, S, T, and U. (See *Figure 9-4.*) One of the major concerns identified by the public is TVA's debt, i.e., the current level of debt and the prospects of the growth in debt if TVA would have completed the unfinished nuclear plants.

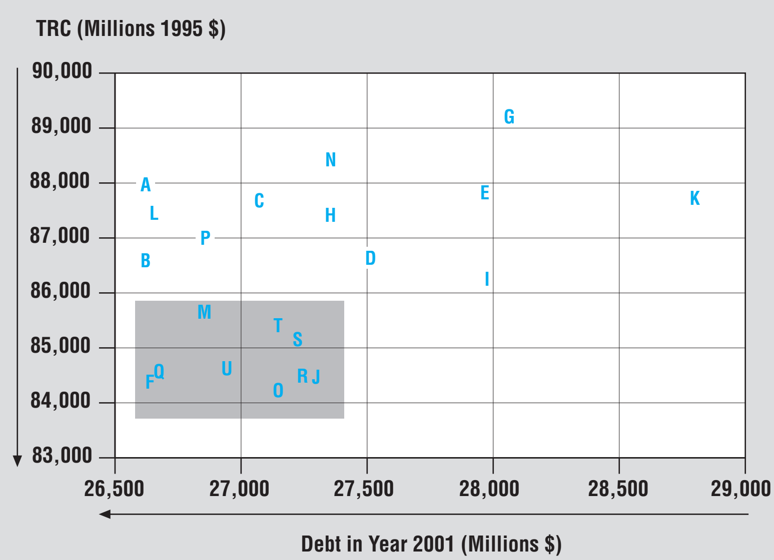
The amount that TVA borrows in the future adds to the debt. TVA borrowings are generally equal to TVA capital expenditures on existing and new plant and equipment less any internal funds that are generated for reinvestment in existing or new plant and equipment. Internal funds for reinvesting in plant and equipment are largely based on depreciation or amortization charges for existing plant and equipment.

All of the strategies identified in *Figure 9-4* indicate that TVA, by itself, will not complete Bellefonte Units 1 and 2, Watts Bar Unit 2, or restore Browns Ferry Unit 1 as nuclear plants. Reducing expenditures on the capital-intensive nuclear plants is one of the major reasons that the projected debt level in 2001 remains below $28 billion.

In addition, the nine low-cost and low-debt strategies include the completion of Watts Bar Unit 1 and Browns Ferry Unit 3 in 1996. These revenue- producing units require relatively small capital expenditures to complete and will be depreciated when the units go into service, thereby providing internal funds to manage debt.

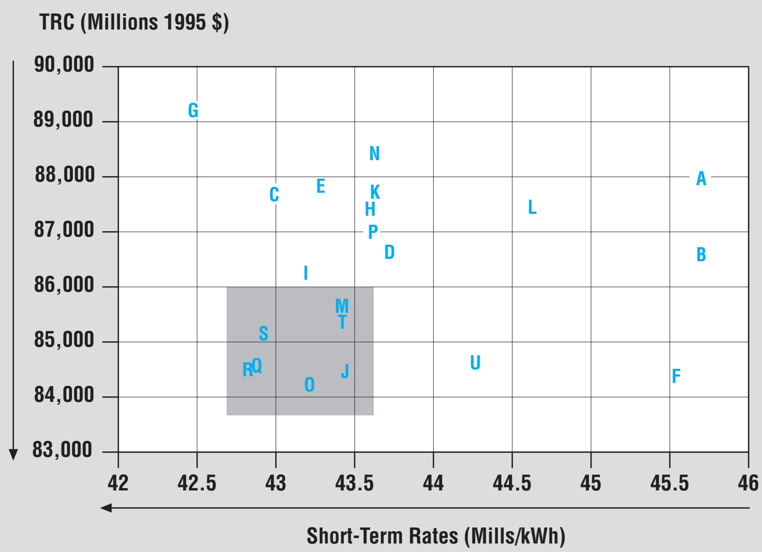
Peaking capacity needs beginning in 1998 and base-load capacity needs in 2001 are met by low capital cost and small-size combustion turbines and combined cycle plants, purchased power from other utilities or purchases of options on future power delivery, demand-side management, and other low-capital cost resource options. These resource options result in lower capital expenditures and help maintain the TVA debt level

FIGURE 9-4. **Strategy Trade-Off for Debt in Year 2001 vs. Total Resource Costs**



The nine strategies within the box have relatively low debt and low costs.

FIGURE 9-5. **Strategy Trade-Off for Short-Term Rates vs. Total Resource Costs**



The seven strategies within the box have relatively low short-term rates and low costs.

below the $30 billion statutory limit.

TVA also closely scrutinizes, monitors, and controls capital expenditures on existing plant and equipment. Most capital expenditures other than for safety or regulatory compliance are subjected to cost-effective tests to maintain low costs and electric rates, as well as reduce TVA's need to borrow additional money.

Thus, the strategies identified in *Figure 9-4* indicate that TVA can manage its debt by controlling capital expenditures on existing and new plants. By controlling capital expenditures, these expenditures will not exceed the amount of internal funds and therefore require little or no new borrowing. Without borrowing additional money, TVA can maintain or lower the level of debt.

Most importantly, TVA's Board of Directors indicated that TVA would limit its debt. This limit on debt would be less than TVA's statutory limit of $30 billion. These strategies result in debt that is $2 to $3 billion less than TVA's statutory limit of $30 billion. Long-term costs are in a range of $84 to $86 billion or a range of 2.4 percent.

Short-Term Rates Versus Total Resource Costs

Seven strategies result in low short-term rates and low long-term costs. These are Strategies J, M, O, Q, R, S, and T. (See *Figure 9-5.)* Strategies F and U have high rates but low costs. Strategy G has high costs but low short-term rates.

All of the strategies that are low cost, with the exception of Strategies M and F, contain the Bellefonte conversion to a coal gasification plant with the production of both electricity and a chemical coproduct.

The Bellefonte conversion option alone reduces the total resource costs approximately $1,500 million. The Bellefonte conversion option reduces both costs and electric rates. Costs and rates are reduced because the sale of the chemical coproduct provides benefits that reduce the cost of electricity. In addition, this option minimizes electric rates because much of the existing plant at Bellefonte can be used in the conversion that reduces the potential write-off of unused plant and equipment.

Without the Bellefonte conversion options, there would be more of a trade-off between costs and short-term electric rates.

Several strategies, such as Strategy F and Strategy U, have relatively low total resource costs but higher short-term rates. For example, Strategy F has electric rates that are 2 to 2.5 mills greater, or 5 to 7 percent greater, than the low-cost and low-rate strategies in *Figure 9-5*. In addition, Strategies B, L, and F could be lower cost if they included the Bellefonte conversion option.

Strategies B, L, U, and F all contain more demand-side management (2,500-5,000 megawatts in 2010) than the seven low-cost and low-rate strategies (1,500 megawatts in 2010) shown in the shaded area of *Figure 9-5*. Strategies with more demand-side management tend to reduce total resource costs.

Although the strategies that have more demand-side management can have lower costs, they also have higher short-term and long-term electric rates.

As indicated in Chapter 5, Evaluation Criteria, the total resource costs measure the net benefits, benefits minus costs, to participants in the demand-side management programs. The participants in demand-side management receive benefits from reduced electric bills. Generally, the benefits exceed the cost of installing demand-side management measures. The non-participants' benefits in demand-side management programs are negative (costs exceed benefits) since the electric rates increase—raising their electric bills without a corresponding savings. Electric rates are increased since the revenue loss from reduced sales plus direct demand-side management costs exceeds the benefits of reduced generation costs. The total resource costs are generally reduced by demand-side management activities because the benefits to participants exceed the costs to non-participants in the demand-side management activity.

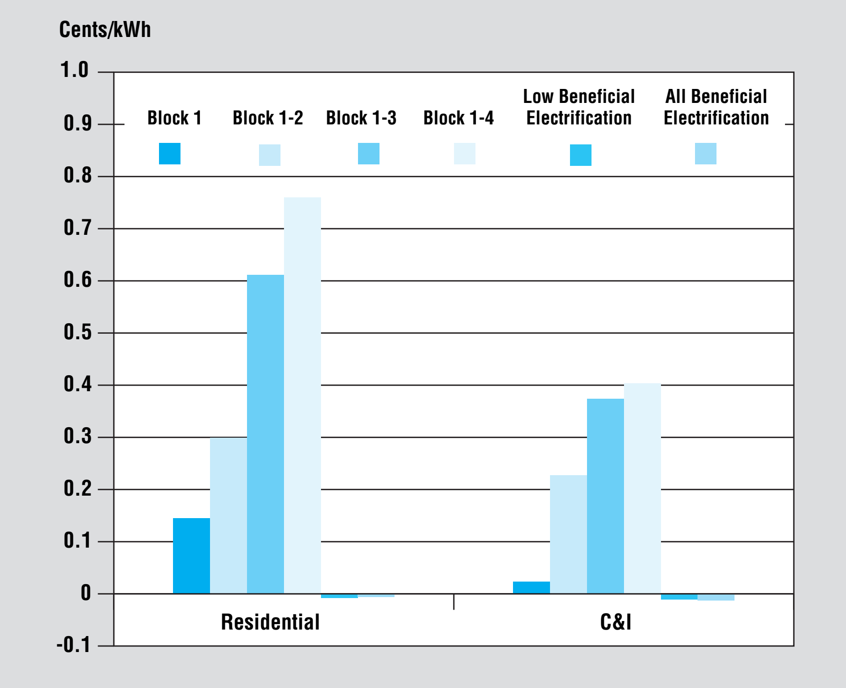
Although there is a reduction in total resource costs with more demand-side management, a portion of the benefits received by the participants is paid by non-participants' increased electric rates and bills. This is commonly referred to as cross-subsidization between participants and non-participants. The higher electric rates and bills for non-participants can be for consumers within the same rate class (e.g., residential) or for consumers in other rate classes, such as industrial customers.

The multi-attribute trade-off analysis examines both total resource costs and electric rates as important criteria for choosing strategies.

An alternative to choosing lower cost or lower rate strategies is to mitigate the effect on electric rates associated with demand-side management activities. There are several possible approaches to mitigating the electric rate effects of demand-side management.

First, demand-side management activities that do not increase electric rates can be implemented. Activities can be implemented such as load management, which reduces peak demands on the power system, and market transformation activities in which the participants or beneficiaries of the demand-side management activity pay the costs. Of the demand-side management activities identified in Chapter 8, the load management of residential and commercial water heating and cooling reduces peak demands without increasing electric rates to non-participants. Two important market transformation activities identified in Chapter 8 are the manufactured homes program and the comprehensive commercial and industrial finance program. With these programs the consumers that receive the benefits of increased energy efficiency and lower electric bills will pay more of the direct costs, resulting in lower impacts on electric rates

FIGURE 9-6. **Rate Changes by Class of Service Due to Demand-Side Management for Fiscal Year 2000**



to the non-participating consumers.

Second, electric rate increases can be more appropriately allocated to the residential or commercial and industrial rate classes. If costs and the loss of revenues are allocated to those classes of service receiving the benefits of demand-side management, then the rate increases will differ from the average rate increase.

The increase in electric rates for residential, commercial, and industrial customer classes for the four blocks of demand-side management and the two blocks of beneficial electrification are shown in *Figure 9-6*. The rate increases are shown for the year 2000. Residential electric rates will increase by a larger amount than commercial and industrial rates for all blocks of demand-side management. Commercial and industrial electric rates show almost no change for the first block of demand-side management. Beneficial electrification results in almost no change in electric rates.

Thus, the electric rate increases are associated with the classes of customers that generally receive the benefits from the demand-side management activity. Note that within a rate class the non-participants will experience an increase in electric rates.

Third, the revenue loss that results from increased demand-side management activities can be reduced by more closely matching cost savings with the revenue changes by changing the overall rate structure or pricing policy. By more closely matching the revenue loss with the costs savings or benefits, the effect on electric rates can be reduced or eliminated. Two such approaches are real-time pricing mechanisms and the unbundling of electric services. With real-time pricing, prices of electricity on an hour-by-hour basis are based on the incremental costs of electric supply. Thus, for any changes in electricity demand, revenue changes match cost changes, which eliminates any cross-subsidization among consumers. TVA's Economy Surplus Power program is a form of real-time pricing for non-firm or interruptible electric power.

The changing competitive structure of the electric industry is resulting in services associated with the delivery of electric power being unbundled. For example, recent proposed actions by the Federal Energy Regulatory Commission (FERC) are likely to result in transmission services being separately priced from generating services associated with the delivery of electric power. Likewise, other ancillary services to transmission, such as voltage control, could be separately priced in the delivery of electricity. Generating services could also be unbundled by time period (e.g., time-of-day rates) or by type of generation such as peaking, base-load generation, and back-up power for emergencies. This unbundling of services results in prices more closely matching the cost of delivering such services and again reducing the cross-subsidization associated with changes in electricity demands. TVA is currently reviewing and investigating its real-time pricing options and the unbundling of electric services.

All of these approaches to reducing the impact of electric rates of demand-side management activities are being, or will be investigated by TVA now or in the near future. As these investigations are concluded and rate or pricing policies change, TVA will re-evaluate the changes in costs and electric rates associated with demand-side management activities.

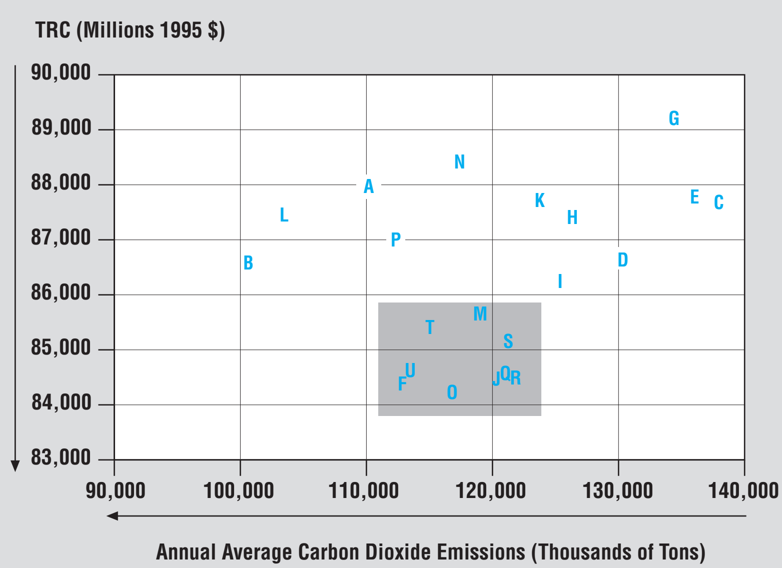
Carbon Dioxide Emissions Versus Total Resource Costs

Nine strategies have low carbon dioxide emissions and low long-term costs. These 9 are Strategies F, J, M, O, Q, R, S, T, and U. Strategies B and L have lower emissions but higher costs. Most environmental measures are correlated (they track with one another); therefore, carbon dioxide emissions are a good surrogate for all environmental measures.

Lower environmental emissions could have been achieved with more demand-side management (Strategies B and L), but only at higher costs as shown in *Figure 9-7*, and higher short-term electric rates shown in *Figure 9-5*.

As indicated in the previous discussion of strategy development, the trade-off between lower electric rates and lower environmental emissions was mitigated. This mitigation occurred through strategies that included clean coal technologies such as integrated gasification combined cycle; renewables such as wind power, the burning of landfill methane in fuel cells, and hydro modernization; and the use of lower carbon dioxide emitting technologies such as natural gas combined cycle, coalbed methane burned in fuel cells, and the repowering of existing coal units with natural gas.

FIGURE 9-7. **Strategy Trade-Off for Average Annual Carbon Dioxide Emissions vs. Total Resource Costs**

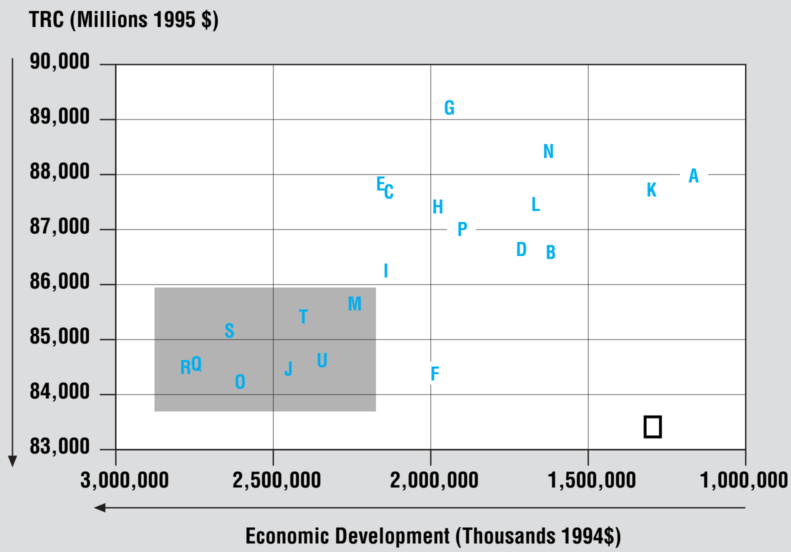


The nine strategies within the box have low to moderate levels of carbon dioxide emissions and relatively low costs.

Economic Development (Personal Income in the TVA Region) Versus Total Resource Costs

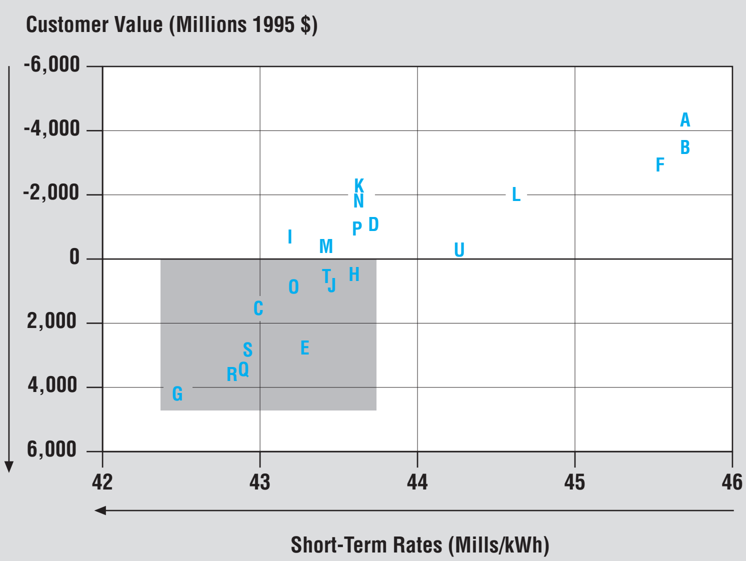
Eight strategies have a positive impact on regional income and low long-term costs. These are Strategies J, M, O, Q, R, S, T, and U. (See *Figure 9-8*.)

FIGURE 9-8. **Strategy Trade-Off for Economic Development vs. Total Resource Costs**



The eight strategies within the box have low costs and high levels of economic development benefits. Economic development is measured by personal income in the TVA region.

FIGURE 9-9. **Strategy Trade-Off for Short-Term Rates vs. Customer Value**



The ten strategies within the box have low short-term rates and high customer value.

Short-Term Rates Versus Customer Value

Ten strategies have low short-term rates and high customer value. These are Strategies C, E, G, H, J, O, Q, R, S, and T. (See *Figure 9-9.*) Four strategies—C, E, G, and H—had not been previously identified as best performers. They emphasize additional off-system sales and beneficial electrification. Since off-system sales and beneficial electrification increase value, these activities also are included in strategies M, O, Q, R, and S.

A summary of trade-off graphs for the 21 strategies as compared to the reference case is shown in a strategy index, illustrated as *Figure 9-10*. The numbers in bold type represent im-provements over the reference case.

From the trade-off graphs and the summary (*Figure 9-10*), there are 13 strategies that could possibly produce two or more of the following: low cost, low debt, low electric rates, low environmental emissions, high economic development, and high customer value. From these strategies several were eliminated.

- Strategies F and U produce low cost and improved environment, but were eliminated due to the higher short-term electric rates.
- Strategies G and E produced high customer value, but increased environmental emissions and debt. In these strategies value was created by beneficial electrification and off-system sales. These customer service options were included in other strategies such as Q, R, and S.
- Strategy C also had higher value, but was eliminated due to high environmental emissions.
- Strategy H also had high value,

FIGURE 9-10. **Summary of Strategy Evaluations**

		Customer Value Test Contribution Split ($mil.)	TRC ($mil.)	Short-Term Rates (mills/kWh)	Total Debt 2001 ($mil.)	CO_2 (kTons/yr.)	SO_2 (kTons/yr.)	Solids (kTons/yr.)	Annual Average Income ($mil.)
D	Reference (Combined Cycle, Purchased Power, Coal)	(1,076)	86,634	44	27,514	130,352	563,048	6,166,437	1,711
		Relative to Reference Case	Percent of Reference Case						
A	Min CO_2—Nat Gas Repowering of Existing Coal	(4,331)	1.02	1.05	**0.97**	**0.85**	**0.86**	**0.79**	0.68
B	Min CO_2—Nat Gas Repowering of Existing Coal and Renewables	(3,470)	1.00	1.05	**0.97**	**0.77**	**0.86**	**0.82**	0.95
C	Low-Cost Producer (Coal-Based)	**1,633**	1.01	**0.98**	**0.98**	1.06	**0.98**	1.22	**1.25**
D	Reference (Combined Cycle, Purchased Power, Coal)	(1,076)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
E	Max Customer Value Index—Off-System Sales, High BE, Declining Block Pricing	**2,779**	1.01	**0.99**	1.02	1.04	**0.92**	1.29	**1.26**
F	Low TRC/High DSM	(2,925)	**0.97**	1.04	**0.97**	**0.87**	**0.87**	**0.96**	**1.16**
G	Maximum Sales	**4,210**	1.03	**0.97**	1.02	1.03	1.02	1.02	**1.13**
H	Maximum Capacity Diversity	**486**	1.01	1.00	**0.99**	**0.97**	1.01	1.00	**1.16**
I	Bellefonte Nuclear Partnership	(681)	1.00	**0.99**	1.02	**0.96**	**0.97**	**0.99**	**1.25**
J	Bellefonte Coproduct, Renewables, IPPs	**820**	**0.97**	**0.99**	**.99**	**0.92**	**0.96**	**0.94**	**1.43**
K	Defer and Build BFN 1 and WBN 2 with Reference Expansion	(2,197)	1.01	1.00	1.05	**0.95**	**0.96**	**0.98**	0.76
L	Minimum CO_2 with Less DSM	(2,005)	1.01	1.02	**0.97**	**0.79**	**0.88**	**0.83**	0.97
M	Combined DSM and Off-System Sales	(397)	**0.99**	**0.99**	**0.98**	**0.91**	**0.91**	1.08	**1.31**
N	Decentralized Generation with More Renewables	(1,891)	1.02	1.00	**0.99**	**0.90**	1.01	**0.97**	.95
O	Bellefonte Coproduct, More DSM, More Off-System Sales	**872**	**0.97**	**0.99**	**0.99**	**0.90**	**0.92**	**0.94**	**1.52**
P	Low-Cost Renewables, Low-Price DSM, Repowering	(938)	1.00	1.00	**0.98**	**0.86**	**0.92**	**0.87**	**1.11**
Q	Flexible Strategy with External Options	**3,450**	**0.98**	**0.98**	**0.97**	**0.93**	**0.90**	**0.97**	**1.61**
R	Flexible Strategy with Internal Options	**3,511**	**0.98**	**0.98**	**0.99**	**0.93**	**0.93**	**0.96**	**1.62**
S	Low Cost, Low Rates, Improved Environment	**2,829**	**0.98**	**0.98**	**0.99**	**0.93**	**0.93**	**0.96**	**1.54**
T	Low-Cost Renewables, Low-Price DSM, Repowering, BLN Coproduct Partnership	**542**	**0.99**	**0.99**	**0.99**	**0.88**	**0.92**	**0.85**	**1.40**
U	Low-Cost Renewables, More DSM, Repowering, BLN Coproduct Partnership	(284)	**0.98**	1.01	**0.98**	**0.87**	**0.91**	**0.85**	**1.37**

All 21 strategies are evaluated for selected criteria and compared to the reference or no action alternative strategy (Strategy D). The customer value is measured in millions of dollars and the other criteria are compared to the reference strategy. The reference strategy is indexed as1.0. Strategies whose criteria are in bold type are better than the reference strategy.

but was eliminated due to the high resource costs. In addition, this strategy contained many options contained in Strategies J, M, Q, R, S, and T.

This analysis identified seven strategies as having low cost, low debt, low electric rates, low environmental emissions, high customer value, and high impact on economic development. These strategies are as follows:

- Strategy J – Bellefonte Coproduct, Renewables, Independent Power Producers

- Strategy M – Combined Demand-Side Management and Off-System Sales
- Strategy O – Bellefonte Coproduct, More Demand-Side Management, More Off-System Sales
- Strategy Q – Flexible Strategy with External Options
- Strategy R – Flexible Strategy with Internal Options
- Strategy S – Low Cost, Low Rates, Improved Environment
- Strategy T – Low-Cost Renewables, Low-Price Demand-Side Management, Repowering, Bellefonte Coproduct Partnership

Environmental Consequences

This section summarizes potential environmental impacts associated with alternative energy strategies. It compares the impacts of alternative strategies and provides the important findings of TVA's environmental analysis for Energy Vision 2020.

TVA'S ANALYTICAL APPROACH REDUCES THE RISK OF ADVERSE ENVIRONMENTAL IMPACTS ASSOCIATED WITH STRATEGIES

The analytical approach used for Energy Vision 2020 is the multi-attribute trade-off method. This approach allows TVA to integrate—quantitatively—the identified environmental impacts and formulate strategies that mitigate them.

TVA developed more than 2,000 different strategies for Energy Vision 2020. These strategies consist of different combinations of energy resource options that were first screened for acceptable performance using multiple criteria, including environmental criteria. In this process, the environmental performance of the strategies was fully integrated into the evaluation in the same manner as financial, rate, economics, and other criteria. Environmental impacts of each strategy are compared to all other evaluation criteria and to all other strategies on an objective basis. This process identified real trade-offs among criteria. One of the most important trade-offs occurred between better environmental performance and electric rates. Achieving better environmental performance (less impacts) typically produces higher costs or rates. In the past, utilities usually have had to choose between lower costs or rates or better environmental performance.

The integrated multi-attribute trade-off method allowed TVA to mitigate potential environmental trade-offs by reformulating strategies to lessen the degree of trade-off. Energy resource options that were primarily responsible for producing undesirable results in either rates or environmental areas were replaced by options that produced more desirable results. These modified strategies were then reintegrated and their performance with respect to the evaluation criteria and trade-offs was reexamined. This was done several times until seven modified strategies were created that respond reasonably well to all Energy Vision 2020 criteria, including environmental criteria. Potential trade-offs were sharply reduced.

With the seven strategies, it is possible to meet the future needs of TVA's customers with much better environmental performance compared to the reference strategy and other unmitigated strategies.

AIR IMPACT SUMMARY

This section summarizes the differences among TVA's final energy strategies with respect to potential impacts on air resources. Chapter 3 provides an overview of air quality issues, existing air quality impacts, sources of air emissions, air pollution trends, and emerging regulations. The air impacts considered in Energy Vision 2020 are human health impacted by inhalation, visibility, crop and forest productivity, materials damage, and greenhouse gases.

FIGURE 9-11. **Air Quality Impact Environmental Indices for Each Strategy and Impact Area**

Strategy	Health-Inhalation	Visibility Impairment	Forest & Crops Productivity	Materials Damage	Greenhouse Gases
D- Reference	1.00	1.00	1.00	1.00	1.00
J	0.98	0.97	0.98	0.97	0.93
M	0.94	0.93	0.95	0.93	0.91
O	0.95	0.94	0.96	0.94	0.90
Q	0.94	0.92	0.95	0.93	0.93
R	0.95	0.94	0.96	0.95	0.93
S	0.95	0.94	0.96	0.95	0.93
T	0.91	0.91	0.91	0.91	0.87

Air indices have been developed for health-inhalation impacts, visibility impairment, forest and crop productivity, materials damage, and greenhouse gases.

Indices were developed to help characterize how the emissions associated with alternative strategies might contribute to these four air impact categories. *Figure 9-11* shows these indices for the final strategies. How these indices were derived is explained in Volume 2, Technical Document 1, Comprehensive Affected Environment. TVA's final strategies were compared to the "No Action" strategy, which is the reference strategy (Strategy D). As indicated, Strategy D was assigned a value of 1.0. The values for the other final strategies then indicate whether they are better or worse than Strategy D with respect to the impact in question (a value greater than 1.0 indicates a worse effect, less than 1.0 a better effect).

TVA's Existing Energy Resources Are the Primary Contributors to Impacts

One of the most important conclusions to be drawn from TVA's Energy Vision 2020 evaluation is that TVA's existing coal-fired units are responsible for most of TVA's contribution to the identified environmental impacts. TVA's coal-fired plants produce air pollution, water pollution, and solid waste. These environmental outputs are associated with a number of environmental problems.

TVA's contribution to many environmental problems has been substantially reduced over the years and is being reduced still further. For example, TVA's sulfur dioxide emissions from its coal-fired units have been reduced by over 60 percent since the mid-1970s and will be reduced still further in response to the Clean Air Act Amendments of 1990. These reductions lessen TVA's contribution to such impacts as acid rain and visibility impairment. However, compared to most new energy resource options, TVA's existing coal-fired units are significantly worse environmental performers.

Energy Vision 2020 focuses primarily on what additional energy resource options, if any, should be added to TVA's system in the future. Consequently, repowering of selected less-efficient coal-fired units is one of the better options for reducing emissions.

Greenhouse Gas Emissions

There remains considerable uncertainty regarding the possible effect of carbon dioxide and other emissions on global climate. However, at the Earth Summit in Rio de Janeiro, Brazil in June 1992, the United States and over 150 other nations signed the United Nations Framework Convention on Climate Change, establishing the objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous manmade interference with the climate system. In October 1993, the President announced the Climate Change Action Plan which has the goal of returning United States greenhouse gas emissions to 1990 levels by the year 2000. As part of this action plan the United States Department of Energy initiated the Climate Challenge which is a voluntary program to manage United States electric utility greenhouse gases through reduction, avoidance, or sequestering of greenhouse gases.

On April 20, 1994, the Climate Challenge Memorandum of Understanding was signed by the Department of Energy, four utility organizations, and TVA. Subsequently, 104 individual Climate Challenge Participation Accords have been signed with the Department of Energy that represent 487 utilities including TVA. The efforts taken by TVA and the other 450 plus Climate Challenge participants will help mitigate possible negative effects utility emissions may have on global climate in a more cost-effective manner than other control measures such as emissions regulations or carbon taxes. A 22.7 million ton reduction in carbon dioxide by the year 2000 is committed to in TVA's Climate Challenge Participation Accord. These reductions are projected from TVA's 1987 to 1990 baseline emissions and the emissions projected by a year 2000 modified reference case. Primarily, TVA greenhouse gas reductions by the year 2000 come from increased use of nuclear power, biomass cofiring, demand-side management programs, fossil-fueled power plant efficiency improvements, transmission system improvements, and hydroelectric power plant modernization.

Other Air Quality Impacts

A number of other conclusions can be derived from Energy Vision 2020's assessment of potential air resource impacts:

- Although coal usage is projected to increase under all strategies, sulfur dioxide and nitrogen dioxide emissions are expected to decrease compared to 1996 levels.
- Sulfur dioxide emissions are projected to decrease from 1996 levels by 47-51 percent in 2020, depending on the strategy.
- Nitrogen oxides emissions are projected to decrease by 10-20 percent by 2000, then increase, but still remain some 3-13 percent below 1996 levels.
- For all strategies, decreases in TVA's contribution to human health impacts, visibility impairment, decreased forest and crop productivity, and materials degradation are expected.

- TVA's contribution to ozone-related impacts is expected to be reduced under all strategies, but TVA's reductions are likely to be offset by emission increases elsewhere in the region. (Mobile source emissions are projected to increase substantially.)
- Among the final strategies, only Strategy D (the reference strategy) and Strategy T (including low-cost renewables) show a noticeable difference in air resource impacts. The reference or "No Action" strategy uses the most coal and has the greatest impacts. Strategy T repowers several existing coal-fired units and uses the most natural gas and renewable resources. This results in a reduction in TVA's contribution to impacts ranging from 9 to 13 percent.

WATER RESOURCE IMPACT SUMMARY

This section summarizes the differences among TVA's final strategies with respect to potential impacts on water resources. Three water-quality impacts were considered: human health impacts by ingestion, impacts on water supply and waste assimilation, and impacts on fish, aquatic life, and aquatic biodiversity. Chapter 3 provides an overview of water quality issues, existing water quality impacts, sources of pollution, water pollution trends, and regulation.

FIGURE 9-12. **Water Quality Impact Environmental Indices for Each Strategy and Impact Area**

Strategy	Health-Ingestion	Water Supply & Waste Assimilation	Fish and Aquatic Life and Biodiversity
D - Reference	1.00	1.00	1.00
J	1.00	1.00	0.99
M	1.01	1.00	1.00
O	1.00	0.99	0.99
Q	1.01	0.99	0.99
R	1.01	1.00	1.00
S	1.01	1.00	1.00
T	0.92	0.99	0.96

Water indices have been developed for health-ingestion, water supply and waste assimilation, and fish and aquatic life and biodiversity.

As with air resource impacts, indices were developed to help characterize how alternative energy resources strategies may contribute to these impact categories. *Figure 9-12* shows these indices. TVA's final strategies are compared to the "No Action" strategy, which is the reference strategy for Energy Vision 2020 (Strategy D). As indicated, there are only slight differences among TVA's final seven strategies and Strategy D for most water resource impacts. Because less coal is burned under Strategy T (low-cost renewables) and coal use produces some water resource-related impacts, only this strategy shows a noticeable improvement with respect to potential impacts.

The water health by ingestion index uses three weighted measures: power production from nuclear, coal-fired, and peaking hydro. Hydro peaking and nuclear power production are constant for all seven final strategies, as well as the reference strategy. As a result, differences in coal-fired (existing plants) power production governs the index. Strategies M, Q, R, and S all have increased coal-fired power production from existing plants compared to the reference strategy. This results in index values slightly greater than 1.0.

A number of conclusions can be derived from Energy Vision 2020's assessment of potential water resource impacts. These include:

- The effects of damming rivers, including operation of existing hydroelectric units, is responsible for the more important water resource impacts. However, since no new dams are proposed in the final strategies or the reference strategy, this impact is the same across all strategies.

- Increasing the capacity of TVA's existing hydroelectric plants is environmentally beneficial. This produces new capacity without constructing new plants. New plant construction, particularly a new hydroelectric dam, is more environmentally damaging. Also, new turbine designs used in increasing the capacity of existing hydroelectric plants incorporate technology that introduces oxygen into the water released through the turbine. This increases dissolved oxygen and helps combat the low dissolved oxygen problem that exists today below a number of TVA dams.
- TVA's existing coal-fired plants are responsible for most of TVA's contribution to water pollution. As described in the section on Air Resource Impacts, cost-effective repowering of selected less-efficient coal-fired units provides some of the best options for water quality.
- Repowering or adding capacity at any existing facility is preferable from a water resource perspective because it lessens the risk of impacts to these resources.

LAND RESOURCE IMPACT SUMMARY

The primary land resource issues for Energy Vision 2020 are potential changes in land use and impacts to land resources. Chapter 3 provides an overview of land resource issues and uses. Because land resource impacts tend to be so site-specific in nature, developing indices for such impacts was not helpful. Land resource impacts can be more fully and meaningfully evaluated when proposals to put specific energy resource options in place are made in the future. These impacts will be addressed in subsequent environmental reviews.

However, certain conclusions or observations can be made at this programmatic level of review based on the generic attributes of various energy resource options. *Figure 9-13* shows the estimated total acreage (land use) that would likely be affected by TVA's final strategies and Strategy D, the reference, "No Action," strategy. From the standpoint of land consumption, Strategy T uses the most land. This is due primarily to the extensive acreage that is needed to support wind turbines.

Other conclusions include:

- Resource options that involve expansions at existing plants or the repowering of existing units have little or no land resource impacts.
- The 2,000 megawatts of wind energy capacity in Strategy T is estimated to require 50,000 acres of land at high elevations where the wind resource tends to be found in or close to the TVA region. Wind turbines are also visually prominent and would have some of the most important aesthetic impacts among the various resource options.
- All of TVA's final strategies, including the reference strategy, expand TVA's use of coal. Coal mining and coal combustion waste disposal are two indirect land uses that have

FIGURE 9-13. **Estimates of Direct Land Use for Plant Siting, Power Transmission, and Plant Access for Each Strategy**

Strategy	Megawatts (Year 2020)	Total Land Use (Acres)
D-Reference	16,037	10,883
J	16,456	17,711
M	14,765	16,299
O	15,406	16,080
Q	16,100	15,335
R	16,720	15,685
S	15,976	16,541
T	17,715	61,957

undesirable land resource impacts. Total coal use rises about 35 percent for most strategies compared to current coal use. Only Strategy T is noticeably different, using about 12 percent less coal than the reference or, "No Action," strategy.

- There is sufficient land in the TVA region to allow energy resource options to be put in place without impacting sensitive land resources such as wetlands or endangered species. Land resources should not be a constraint on putting any of the energy resource options identified in TVA's final strategies in place, with the possible exception of wind turbines.

FIGURE 9-14. **Value of Flexibility**

Resource Type	Net Benefits $/MW-Year
PEAKING	
Inflexible combustion turbine (CT)	4,900
Call option (1-year contract)	5,000
Flexible combustion turbine (CT)	6,400
BASE LOAD	
Inflexible combined cycle (CC)	-21,500
Inflexible independent power producers (IPP)	-20,000
Inflexible integrated gasification combined cycle (IGCC)	-6,300
Flexible combined cycle (CC)	800
Flexible integrated gasification combined cycle (IGCC)	1,701
Call option (multi-year contract)	5,000
Call option (1-year contract)	7,000
BLN/coproduct	71,000

The net benefit of flexible options—both TVA-built and external—are greater than the net benefit of inflexible options.

Managing Risk – Hedging Uncertainties

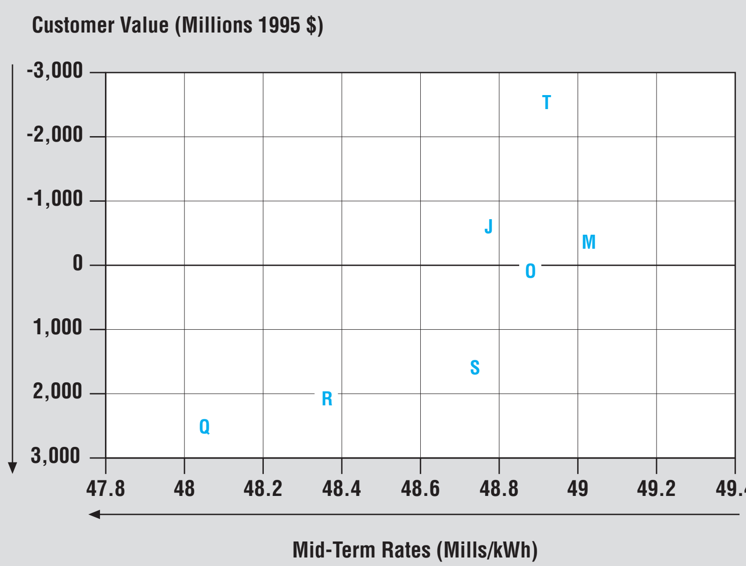
Energy Vision 2020 seeks to provide a robust and flexible set of resource strategies. Robust strategies successfully meet key evaluation criteria for a large range of uncertainties. Flexible options can provide TVA with the ability to respond or adapt to a changing environment as it moves into the 21st century.

Trade-off analysis was used to identify strategies that hedge uncertainties. A strategy hedges an uncertainty if it limits the risk of cost increases compared to other strategies. *Figures 9-14* through *9-21* illustrate the analysis done for the uncertainties of load growth, natural gas pricing, environmental regulations, and nuclear power performance.

UNCERTAINTY IN LOAD GROWTH

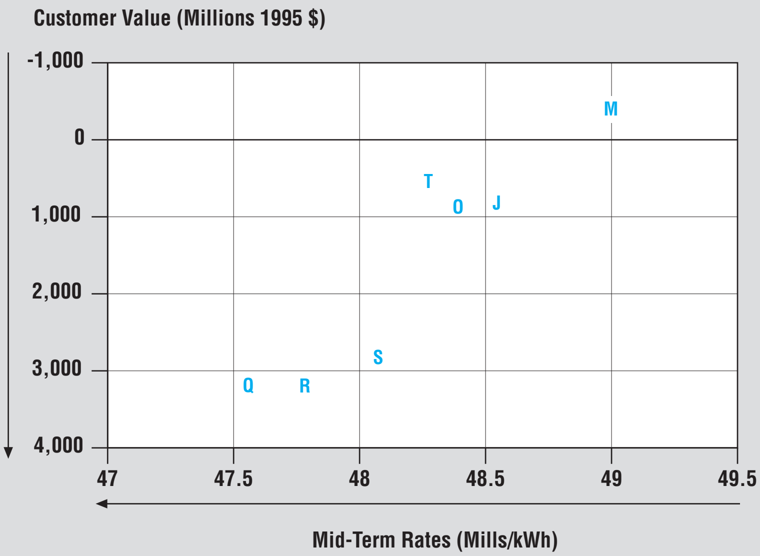
The range of forecasts of future load growth is quite large, indicating, for one, the uncertainty in future competitive conditions. Two strategies were developed that provide resource alternatives and are flexible in the face of uncertain load growth. Strategy Q contains call options on future power. Call options provide TVA the right to buy future power without obligation to buy from suppliers. TVA can buy the right to the power and decide at a later date whether to purchase it. Likewise, Strategy R contains flexible supply-side

FIGURE 9-15. **Value of Flexibility for Load Growth Uncertainty—High Load Growth**



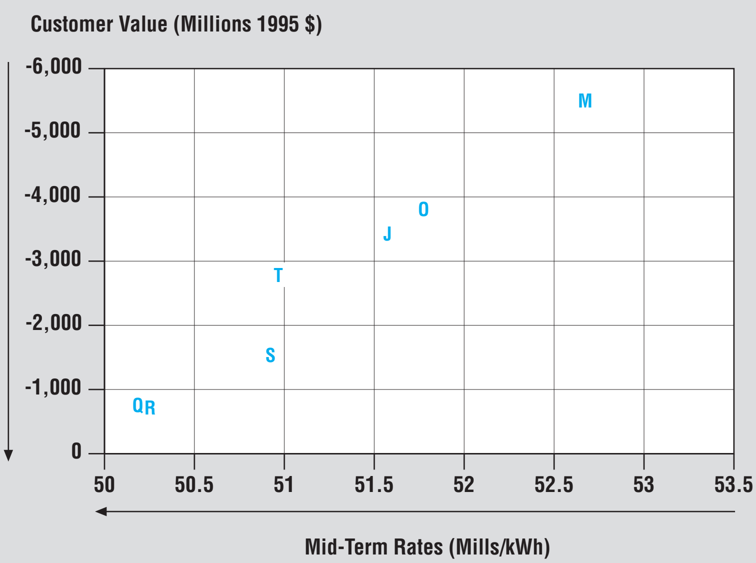
The flexible strategies (Q and R) have lower short-term rates and high value compared to the other key strategies.

FIGURE 9-16. **Value of Flexibility for Load Growth Uncertainty – Medium Load Growth**



The flexible strategies (Q and R) have lower short-term rates and high value with medium load growth as well as high load growth.

FIGURE 9-17. **Value of Flexibility for Load Growth Uncertainty – Low Load Growth**



The flexible strategies (Q and R) have lower short-term rates and high value with low load growth as well as medium and high load growth.

options that TVA would build. These TVA-built options have shorter lead times compared to the inflexible options. (An inflexible option results in significant cost penalties if construction is stopped.)

The net benefits of buying flexible options compared to resource alternatives that do not have flexibility are shown in *Figure 9-14*. The inflexible options, such as a combustion turbine, independent power producer, integrated gasification combined cycle plant, or clean coal plant tend to have negative net benefits. The flexible options for the peaking call option, base-load call option, and flexible integrated gasification combined cycle plant tend to have positive net benefits. Thus, the flexible options tend to have a higher value than the inflexible options.

Trade-off graphs for customer value and electric rates for high, medium, and low load forecasts are shown in *Figures 9-15*, *9-16,* and *9-17*. In these graphs, the flexible strategies—Q and R—tend to have higher value and lower electric rates regardless of the load forecasts. Since these strategies include beneficial electrification, customer value is used as the measure of benefits and costs, rather than total resource cost. As a measurement, total value better captures the benefits and costs associated with increases in electricity consumption from beneficial electrification and variation in load growth.

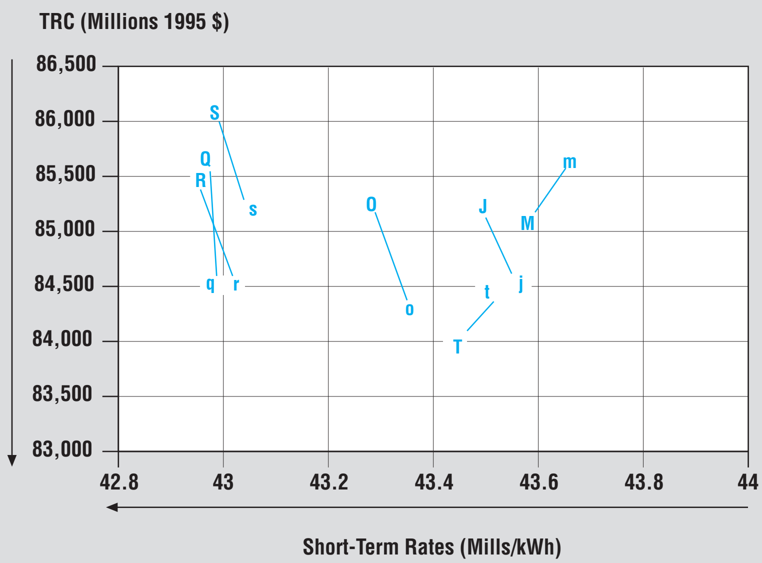
UNCERTAINTY IN NATURAL GAS PRICES

In trade-off analysis, the difference was examined between medium and low natural gas prices. *Figure 9-18* shows the analysis of strategies for the medium and low natural gas prices. (In terms of uncertainty in natural gas prices, most of the public comments indicated TVA's natural gas price forecasts were too high. Recognizing those comments, TVA concentrated on the medium and low natural gas prices.) In *Figure 9-18*, the uncertainties other than natural gas were held at their mid-range values.

In the figure, low natural gas prices are shown in uppercase letters and medium natural gas prices are shown in lowercase letters. The line between the medium and low gas prices indicates the change in total resource cost for each strategy.

Strategies M and T contain clean coal technologies. With Strategy T, costs will increase less than for Strategy M with rising natural gas prices, since Strategy T also contains renewables. Flexibility to adapt to changing gas prices can be provided by including clean coal technologies and renewables in strategies. For example, TVA could build a combined cycle plant with natural gas as the fuel and, at a later time, add coal gasification if natural gas prices increase.

FIGURE 9-18. **Cost Risk Due to Uncertainty in Natural Gas Prices**



J	Low	**j**	Medium	**R**	Low	**r**	Medium
M	Low	**m**	Medium	**S**	Low	**s**	Medium
O	Low	**o**	Medium	**T**	Low	**t**	Medium
Q	Low	**q**	Medium				

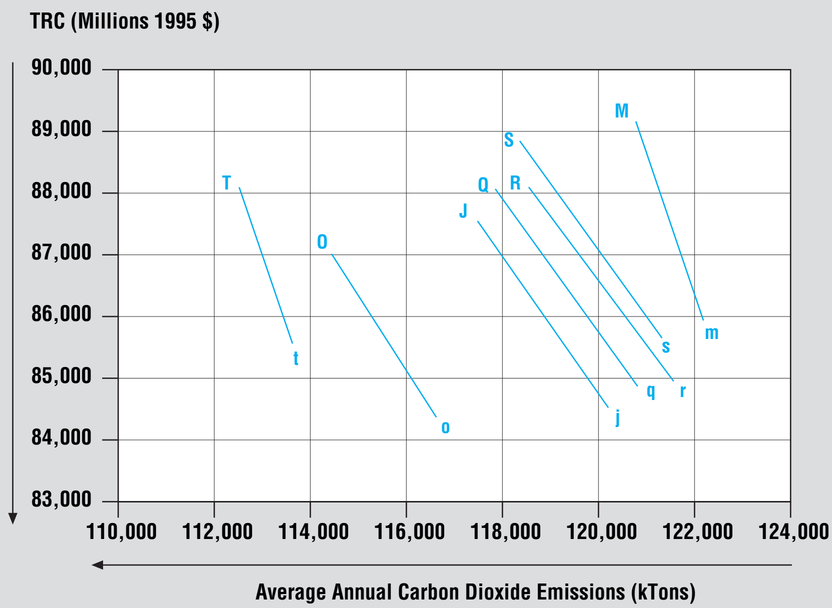
Low natural gas prices are indicated with uppercase letters and medium or higher natural gas prices are indicated with lowercase letters. The length of the line indicates the change in costs due to natural gas price variations.

Several strategies—particularly Strategies J, O, Q, R, and S—contain coal gasification with the production of a chemical coproduct. Chemical coproducts traditionally have been produced with natural gas; therefore, prices of coproducts are based on natural gas prices. High natural gas prices will result in higher prices of the chemical coproduct and lower costs for strategies that contain this option. In other words, for these strategies, higher natural gas prices result in lower costs. The chemical coproduct provides a hedge or offset to rising natural gas prices.

UNCERTAINTY IN CARBON DIOXIDE REGULATIONS

The mid-range future assumes there will be no additional carbon dioxide regulations. *Figure 9-19* illustrates the analysis of the change in costs and carbon dioxide emissions if there are regulations on carbon dioxide emissions. The analysis assumes, as a worst case, a cap on carbon dioxide emissions, with purchases and sales of carbon dioxide allowances at \$10 per ton of carbon dioxide. (Carbon dioxide regulations have been modeled similar to current acid rain regulations, which permit buying and selling of sulfur dioxide allowances.)

FIGURE 9-19. **Low-Cost Risk Due to Carbon Dioxide Regulations**



CO_2 Regulations	J	M	O	Q	R	S	T
No Regulations	j	m	o	q	r	s	t

Lowercase letters indicate costs and carbon dioxide emissions with no carbon dioxide regulations; uppercase letters indicate costs and emissions with carbon dioxide regulations. The length of the line indicates the increase in costs for carbon dioxide regulations.

The analysis indicates that the lower cost strategies are robust; they remain lower cost, even with carbon dioxide regulations. For example, Strategies J, O, Q, and R have relatively low costs without carbon dioxide regulations (lowercase letters) and low costs with carbon dioxide regulations (uppercase letters), compared to other strategies. These strategies are relatively robust because they contain options that have low carbon dioxide emissions or offset carbon dioxide emissions, such as natural gas-based combined cycle plant, fuel cells using landfill methane, renewables, and demand-side management options.

UNCERTAINTY IN AIR AND WATER QUALITY REGULATIONS

The mid-range future was based on current air and water regulations including compliance with the acid rain provisions of current Clean Air Act regulations. Additional air and water quality regulations could occur, which would increase the cost of compliance. The effect on selected strategies for additional air and water regulations is shown in *Figure 9-20*. Sulfur dioxide emissions are used to measure the impacts of both air and water regulations. Current regulations are shown in lowercase letters, and more stringent regulations are shown in uppercase letters. Strategies J, O, R, and Q have lower costs regardless of the uncertainty in air and water regulations.

For some strategies the lines connecting the no regulations case with the regulations case cross. For example, if one begins with a flexible approach such as with Strategy Q, both costs and sulfur dioxide emissions can be minimized with no regulations. With regulations, one might want to switch strategies to Strategy O, which contains more renewables to minimize emissions and costs.

UNCERTAINTY IN NUCLEAR PERFORMANCE

The uncertainty in nuclear performance is represented by variations in capacity factor, operation and maintenance costs, and the cost to complete the nuclear units. All of the strategies except for Strategy K assume that Watts Bar Unit 2 and Browns Ferry Unit 1 are kept in deferral status and canceled in the year 2000. Strategy K assumes that these two units will be kept in deferral status until 2000, at which time construction will resume. Strategy K also assumes that work on Watts Bar Unit 2 and Browns Ferry Unit 1 would be completed in 2005 and 2006, respectively.

Three levels of nuclear performance were considered: poor, moderate and good. As indicated in the trade-off graph in *Figure 9-21*, with moderate or poor performance, the lowest cost strategy—Strategy D, the reference case—defers and cancels both nuclear units. With good nuclear performance, the lowest cost strategy—Strategy K—defers and then completes the nuclear units.

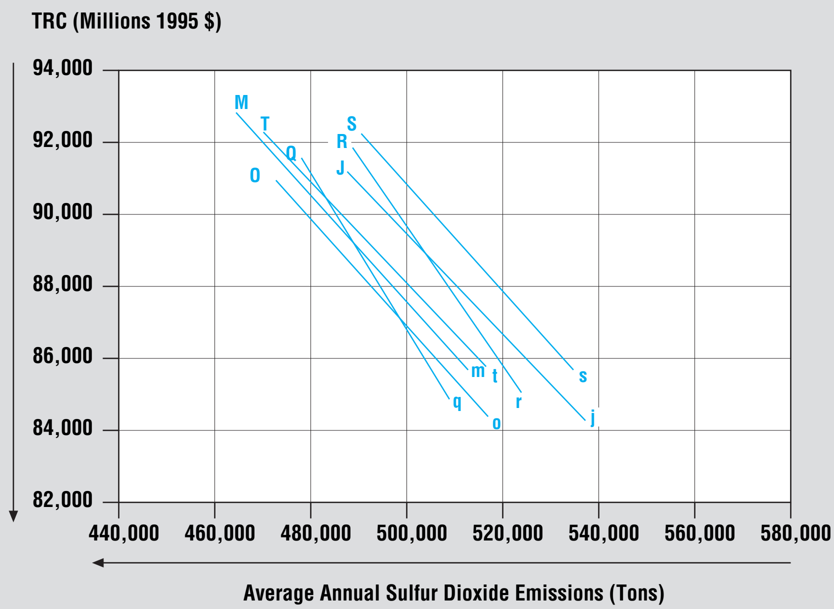
Final Evaluation

A summary of strategy evaluations according to customer value, total resource cost, short-term rates, environment, debt, and economic development, and five uncertainties—load growth, natural gas prices, environmental regulations, nuclear performance, and customer services effectiveness—is illustrated in *Figure 9-22*. Note that the environmental uncertainty combines the uncertainty in carbon dioxide regulations and additional air and water regulations.

After evaluation, seven strategies have emerged that offer lower cost, lower debt, better value, and improved environmental performance and economic development impact, compared to the other strategies. These strategies are as follows:

- Strategy J - Bellefonte Coproduct, Renewables, Independent Power Producers
- Strategy M - Combined Demand-Side Management and Off-System Sales
- Strategy O - Bellefonte Coproduct,

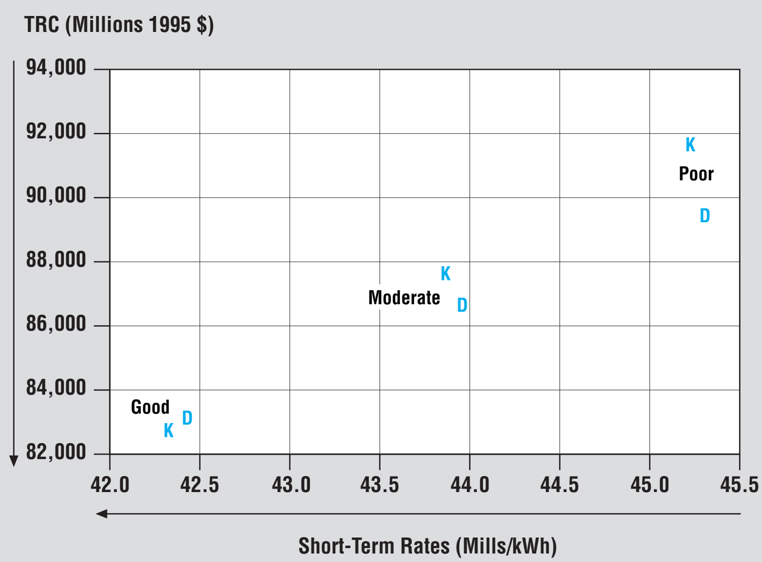
FIGURE 9-20. **Cost Risk Due to Additional Air and Water Regulations**



Additional Regulations	J	M	O	Q	R	S	T
Current Regulations	j	m	o	q	r	s	t

Current air and water regulations are indicated with lowercase letters, and additional air and water regulations are indicated with uppercase letters. The length of the line indicates the cost risk to additional air and water quality regulations.

FIGURE 9-21. **Cost Risk Due to Nuclear Performance Uncertainty**



Nuclear performance uncertainty represents three uncertainties: operation and maintenance cost, capacity factor, and cost to complete construction. Cost and rates are shown for poor, moderate, and good nuclear performance. Except for good nuclear performance, completing Watts Bar Unit 2 and Browns Ferry Unit 1 leads to higher costs.

FIGURE 9-22. **Strategy Performance Matrix**

	CRITERIA						UNCERTAINTY				
Strategy	**Value**	**Cost**	**Rates**	**Environ.**	**Debt**	**Econ. Dev.**	**Load Growth**	**Natural Gas Prices**	**Environ. Reg.** [1]	**Nuclear Perf.**	**Customer Service Effective-ness**
A Minimum CO_2—Natural Gas Repowering of Existing Coal	Poor	Poor	Poor	Good	Good	Poor					
B Min CO_2—Natural Gas Repowering of Existing Coal and Renewables	Poor	Mod.	Poor	Good	Good	Poor			Hedge		
C Low-Cost Producer (Coal-Based)	Good	Mod.	Good	Poor	Good	Mod.		Hedge			
D Reference	Good	Mod.	Poor	Poor	Good	Poor					
E Maximum Customer Value Index—Off-System Sales, High BE, Declining Block Pricing	Good	Poor	Mod.	Poor	Mod.	Mod.	Hedge	Hedge			
F Low TRC, High DSM	Poor	Good	Poor	Good	Good	Mod.		Hedge			
G Maximum Sales	Good	Poor	Good	Poor	Mod.	Mod.	Hedge				
H Maximum Capacity Diversity	Mod.	Mod.	Mod.	Poor	Good	Mod.			Hedge		
I Bellefonte Nuclear Partnership	Mod.	Mod.	Good	Mod.	Mod.	Mod.			Hedge	Hedge	
J Bellefonte Coproduct, Renewables, IPPs	Mod.	Good	Mod.	Mod.	Good	Good		Hedge	Hedge		
K Defer and Build WBN Unit 2 and BFN Unit 1	Poor	Mod.	Mod.	Mod.	Mod.	Poor				Hedge	
L Minimum CO_2 with Less DSM	Poor	Poor	Poor	Good	Good	Poor			Hedge		
M Combined DSM and Off-System Sales	Mod.	Good	Mod.	Mod.	Good	Mod.		Hedge			
N Decentralized Generation with More Renewables	Mod.	Poor	Mod.	Mod.	Good	Poor			Hedge		
O Bellefonte Coproduct, More DSM, More Off-System Sales	Good	Good	Good	Mod.	Good	Good		Hedge	Hedge		Hedge
P Low-Cost Renewables, Low-Price DSM, Repowering	Mod.	Mod.	Mod.	Good	Good	Mod.					
Q Flexible with External Options	Good	Good	Good	Mod.	Good	Good	Hedge	Hedge	Hedge		
R Flexible with Internal Options	Good	Good	Good	Mod.	Good	Good	Hedge	Hedge	Hedge		
S Low Cost, Low Rates, Improved Environment	Good	Good	Good	Mod.	Good	Good		Hedge	Hedge		
T Low-Cost Renewables, Low-Price DSM, Repowering, BLN Coproduct Partnership	Good	Good	Good	Good	Good	Good		Hedge	Hedge		
U Low-Cost Renewables, More DSM, Repowering, BLN Coproduct Partnership	Good	Good	Mod.	Good	Good	Good		Hedge	Hedge		

[1] Includes uncertainty in air, water, and CO_2 regulations

The evaluation of strategies is summarized qualitatively for key evaluation criteria and for the key uncertainties. The qualitative assessment was based on a ranking of the strategies with "good" representing the upper third; "moderate," the middle third; and "poor," the lower third.

More Demand-Side Management, More Off-System Sales
- Strategy Q - Flexible Strategy with External Options
- Strategy R - Flexible Strategy with Internal Options
- Strategy S - Low Cost, Low Rates, Improved Environment
- Strategy T - Low-Cost Renewables, Low-Price Demand-Side Manage- ment, Repowering, Bellefonte Coproduct Partnership

These strategies also provide hedges against the key uncertainties that allow TVA to manage risks.

The Long-Term Plan – Preferred Alternative

Energy Vision 2020 integration results are captured in the long-term plan. The plan sets forth a range of actions TVA can take to meet future needs of its customers.

In developing the long-term plan, TVA has selected a portfolio (also referred to as a bundle) of resource options from the seven key strategies. All of the resource options contained in the seven strategies are included in the portfolio. Much like a portfolio of stocks is chosen to manage risk and accomplish specific objectives, the portfolio of resource options enables TVA to meet customer needs at an acceptable level of risk and meet the objectives of balancing costs, rates, environmental impact, debt, and economic development.

When TVA refers to “balancing” the “environment” or “environmental impacts” in the context of these objectives it is referring to costs of meeting environmental requirements, the consequences of environmental uncertainties, and environmental impacts, expressed both quantitatively and qualitatively, of proposed actions or strategies.

To manage risk, the portfolio provides a robust and flexible set of resource options. Options that are robust can withstand a large range of uncertainties. Flexible options can be altered or modified as TVA moves into the 21st century. Robust and flexible options were identified in the analysis of managing risk.

The long-term plan is presented in *Figure 9-23*. As illustrated, a portfolio of resource options (taken from seven strategies) provides for TVA’s supply-side (peaking and base load), customer service, and environmental requirements.

For example, combustion turbines, purchases of peak power, and call options on peaking power will supply peaking power for 1996-2005. For 2005-2020, compressed air energy storage is added as a supply-side peaking option.

Nine options supply base-load power for 1996-2005. These include call options on base-load power, improvements to existing hydro system, combined cycle plant with pre-siting and engineering, purchases from independent power producers with and without cogeneration, combined cycle repowering of coal-fired plants, renewables—landfill methane and refuse-derived fuel, coalbed methane, Bellefonte or greenfield coal gasification and coproducts with partners, and an additional coal-fired unit at Shawnee Fossil Plant.

FIGURE 9-23. Long-Term Plan

This long-term plan is defined to meet key objectives. The plan is organized by supply-side options for the short term (1996 – 2005) and the long term (2006–2020), customer service options and actions which hedge key uncertainties.

Develop a preferred portfolio of resource options for the long term from key strategies. Objectives of the portfolio are:

1. Balance costs, rates, environment, debt, and economic development.
2. Provide a robust set of resource options or flexibility to adapt to uncertain load growth, future market prices, changes in environmental regulations, and changes in market regulations to manage risk.

Strategies

- J – Bellefonte Coproduct, Renewables, IPPs
- M – Combined DSM and Off-System Sales
- O – Bellefonte Coproduct, More DSM, More Off-System Sales
- Q – Flexible Strategy with External Options
- R – Flexible Strategy with Internal Options
- S – Low Cost, Low Rates, Improved Environment
- T – Low-Cost Renewables, Low-Price DSM, Repowering, Bellefonte Coproduct Partnership

Options		1996 –2005	2006 –2020
Supply	Peaking	• Combustion turbines, purchases of peak power, and call options on peaking power	• Compressed air energy storage (CAES)
	Base Load	• Call options on base-load power • Improvements to existing hydro system • Combined cycle with pre-siting and engineering • Purchases from independent power producers with and without cogeneration • Combined cycle repowering of coal-fired plants • Renewables—landfill methane and refuse-derived fuel • Coalbed methane • Bellefonte coal gasification and coproducts with partners • Additional coal unit at Shawnee • Improvements in existing system • Nuclear partnership	• Wind turbines • Coal refinery • Cascaded humidified advanced turbine (CHAT) • Integrated gasification combined cycle (IGCC) • Integrated gasification with CHAT (IGCHAT)
Customer Service		• DSM—low price and cost (examples of programs)	• Residential new construction • Commercial and industrial comprehensive finance • Industrial motors
		• Beneficial Electrification (examples of programs)	• Residential heating, air conditioning, and water heating • Commercial cooking • Industrial electrotechnologies
		• Flexible DSM and Beneficial Electrification	
Environmental		• Pursue a flexible strategy of fuel switches, scrubbers • Global climate challenge—improvements to existing system, biomass cofiring	

RESOURCE ALTERNATIVES TO MANAGE RISK

Uncertainty	Options
• Load Growth	• Call options on purchases from external suppliers • Flexible internal supply options • Small modular options—landfill methane, coalbed methane, and distributed resource alternatives • Flexible DSM options
• Natural Gas Prices/Coproduct Prices	• Integrated gasification combined cycle (IGCC) • Integrated gasification cascaded humidified advanced turbine (IGCHAT) • Bellefonte coal gasification with a chemical coproduct
• Environmental Regulation—Air, Water, CO_2 Regulation	• Renewables—wind, landfill methane, biomass • Coalbed methane • Aggressive DSM and beneficial electrification • Natural gas-based resource alternatives

Base-load power for 2005-2020 will be supplied by wind turbines, a coal refinery, the cascaded humidified advanced turbine (CHAT), an integrated gasification combined cycle plant, and integrated gasification with CHAT.

In the short- and long-term, TVA will rely on demand-side management and beneficial electrification. Examples of demand-side management include energy efficiency improvements, residential new construction and commercial and industrial finance plans to improve demand-side management. Examples of beneficial electrification include residential heating, air conditioning and water heater programs; commercial cooking programs; and industrial electrotechnology programs.

A flexible strategy of fuel switches and scrubbers, along with system improvements addressing global climate changes and biomass cofiring, are the long-term environmental control options.

In addition, 10 options address 3 key uncertainties: load growth, price of natural gas and coproducts, and environmental regulations.

Call options from external suppliers, flexible internal supply options, and small modular options like landfill methane, coalbed methane, distributed resource alternatives, and flexible demand-side management address load growth uncertainty.

Three options address uncertainty in natural gas and coproduct prices, including an integrated gasification combined cycle plant, integrated gasification cascaded humidified advanced turbine, and Bellefonte coal gasification with a chemical coproduct.

Renewables—wind, landfill methane, and biomass; natural gas-based resource alternatives; coalbed methane; repowering of existing coal-fired plants; and aggressive demand-side management and beneficial electrification address environmental regulations.

The long-term plan or portfolio provides resource options that are largely derived from the seven best strategies previously identified. These resource options will be implemented as necessary to meet customer needs. Thus, this long-term plan also provides for low cost, low debt, low electric rates, improved environment, and high economic development compared to all strategies.

The long-term portfolio is compared to all strategies for the key criteria in *Figure 9-24*. For example, the range of total resource costs for all strategies is from $84.2 to $89.2 billion. The long-term portfolio has a range at the lower end of this range of $84.2 to $85.6 billion. Thus, the long-term portfolio results in the best values for the key criteria.

FIGURE 9-24. **Long-Term Plan – Range of Values for Criteria**

	All Strategies	Long-Term Portfolio
Total Resource Costs (Billions of $)	$84.2 – $89.2	$84.2 – $85.6
Total Debt in 2001 (Billions of $)	$26.7 – $28.8	$26.7 – $27.2
Short-Term Rates (Mills/kWh)	42.5 – 45.7	42.8 – 43.4
Annual Average CO_2 Emissions (Millions of Tons)	101.0 – 138.0	115.0 – 121.6
Personal Income (Millions of $)	$1,100 – $2,770	$2,240 – $2,770
Customer Value (Millions of $)	$-4,100 – $4,100	$-400 – $3,510

ENVIRONMENTAL IMPACTS OF PORTFOLIO ALTERNATIVE

As explained earlier in this chapter, TVA has identified a portfolio of options—taken from the seven final strategies—as its preferred strategy for the long-term plan. Thus, potential impacts depend on those options eventually implemented. Although the impacts cannot be definitively assessed, the impacts of the seven final strategies are likely to provide the boundaries—best and worst case—for the portfolio.

Concerning the environment, it is unlikely that implementation of portfolio options would achieve better or worse environmental performance than the range of impacts for the seven strategies. In any event, impacts of the portfolio are likely to be much less than those associated with the "No Action" alternative, Strategy D.

All the options included in this portfolio are available to TVA management. The specific choices recommended to TVA for implementation are included in the short-term action plan presented in the next chapter.